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B7W WFH WFX

(56) Documents cited
GB 2238283 A GB 1485828 A GB 1386887 A
GB 1357003 A GB 1129112 A GB 1118277 A
GB 1070874 A

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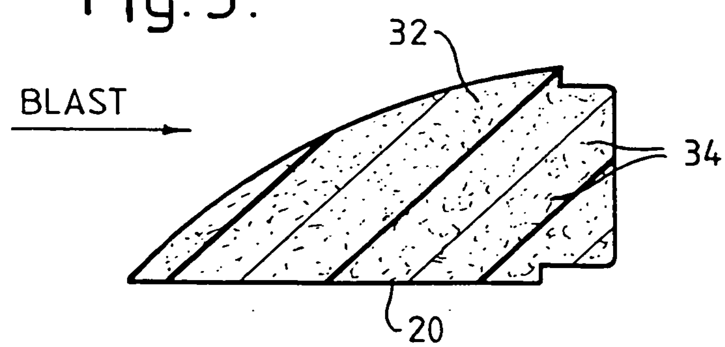
UK CL (Edition K) A5A, B7W WC WFH WFX, C3C, C3N
INT CL$^5$ A62C, B64C
Online databases: CLAIMS, WPI

(54) **Blast absorbing structure**

(57) A blast absorbing structure (20) comprising a first deformable/crushable material (32) for absorbing explosive blast energy by way of conversion to mechanical work and a second material (34) for absorbing explosive blast energy by way of conversion to thermal energy. The first material (32) may be foam or vermiculite for example. The second material (34) may be a powdered metal, a fluid or a gel suspended in or coated onto the first material.



Fig.3.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig. 1.

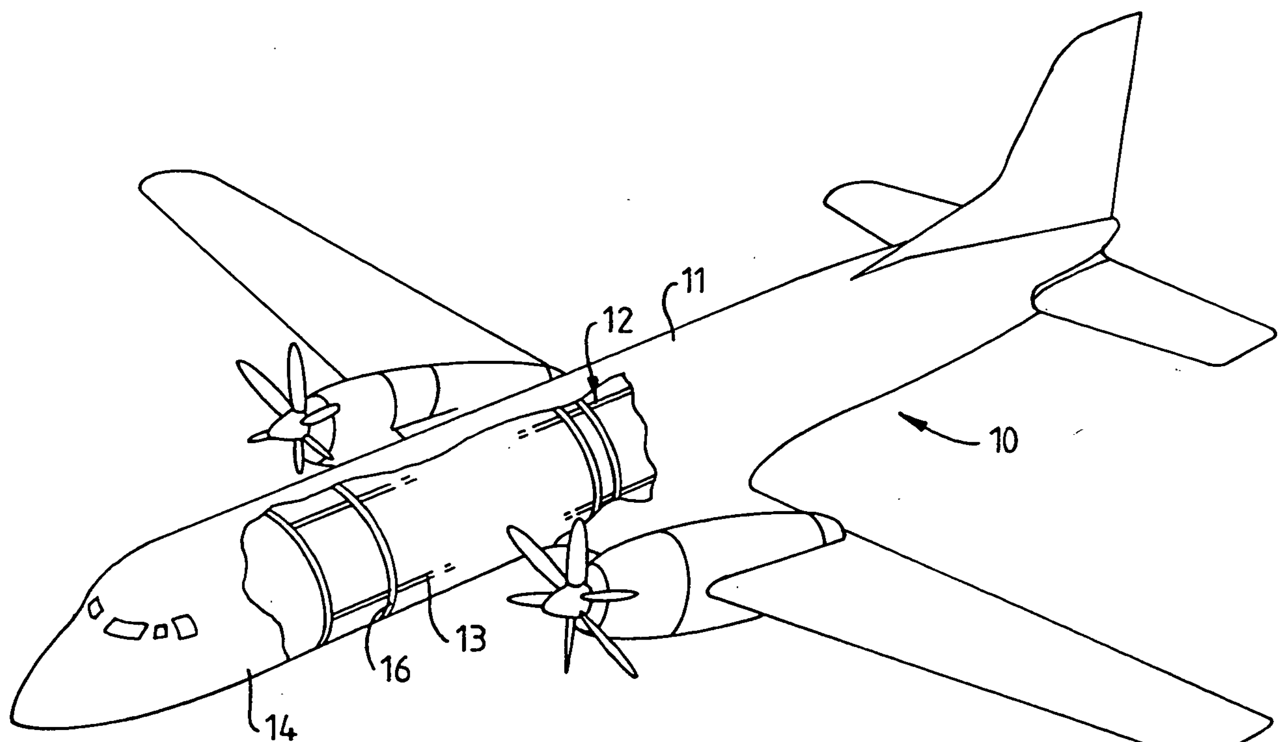


Fig. 2.

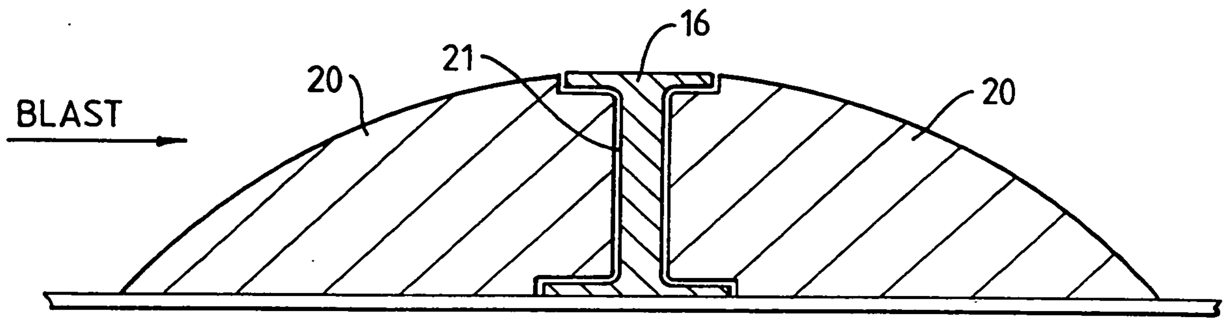



Fig. 3.

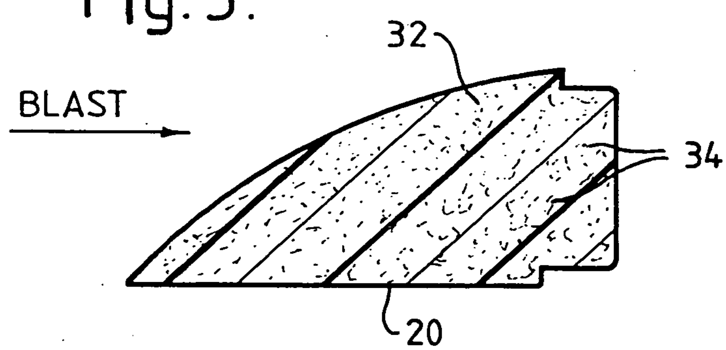



Fig. 4.

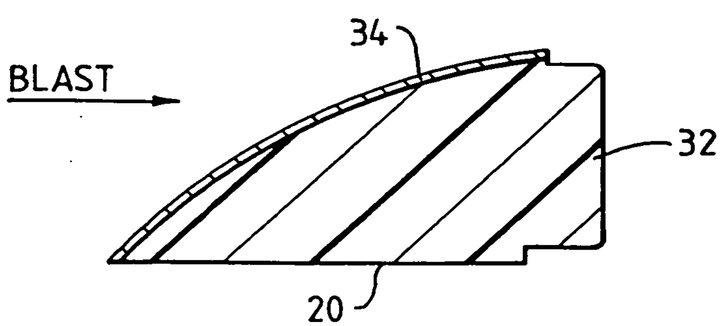


Fig. 5.

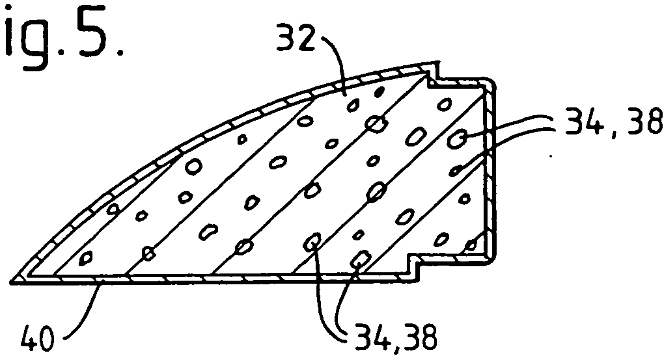



Fig. 6(a).

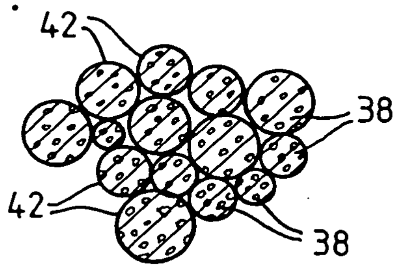
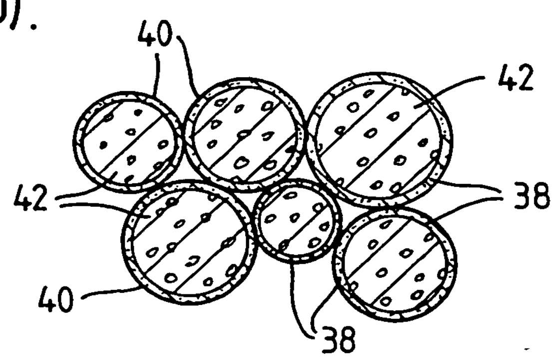



Fig. 6(b).



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# A BLAST ABSORBING STRUCTURE

The present invention relates to blast absorbing structures and relates particularly, but not exclusively, to blast absorbing structures for use in protecting structurally important aircraft and vehicle members or for use in containing explosive blasts.

Conventional aircraft fuselages, for example, comprise a structural framework covered by an outer skin of sheet metal. The framework comprises a plurality of circumferentially extending frames axially spaced from each other and a plurality of longerons which run along the length of the fuselage connecting the frames. The aircraft floor generally comprises a basic suspended framework covered by sheet flooring material. The frames present a large surface area to any shock wave or blast from an internal explosion. It has been found that the force per unit area experienced by the frames as a result of an explosion can be sufficient to cause failure thereof and hence compromise the structural integrity of the aircraft.

The mechanical work done by a pressure wave is essentially compressive 'pdV' work given by the expression $\int Pdx$, for a one dimensional wave, where the integral is effectively over the spatial extent of the pressure distribution. Clearly, changing the pressure distribution, or more correctly, the waveform P, will affect the work done by the wave on the structure through which the wave is propagating.

The blast wave also has a mechanical effect associated with its duration. The impulse a pressure wave imparts is dependent on its waveform and the duration over which it acts; it is given by the expression $\int Pdt$, where the integral is effectively over the interval spanning the fluid-structure interaction. The sharper the waveform, the greater the structural impulse.

Current techniques for blast mitigation are essentially based on mechanical effects and rely on altering the waveform to broaden it, thereby reducing the associated impulse, and letting the work done by the wave act over a larger volume. This is normally achieved by letting the wave propagate through a crushable material, either a solid foam or a vermiculite. In this manner energy is extracted from the propagating wave and its destructive effect reduced.

It will be appreciated that the shock absorbing capabilities of the above structure is directly proportional to its size. In certain circumstances, such as for example in an aircraft where space is limited, it would be impracticable to incorporate structures of a sufficiently large size to ensure adequate protection of structurally important aircraft members from the explosive blast produced as a result of an internal explosion.

There therefore exists a requirement for a blast absorbing structure of reduced size and/or improved blast absorbing capabilities.

It is an object of the present invention to provide a blast absorbing structure suitable for protecting structurally important

aircraft or vehicle members or for use in containing explosive blasts which fulfils the above mentioned requirement.

Accordingly, the present invention provides a blast absorbing structure comprising a first deformable/crushable material for absorbing explosive blast energy by way of conversion to mechanical work and a second material for absorbing explosive blast energy by way of conversion to thermal energy.

Preferably, the first material comprises a foam as foams can be easily formed or moulded into a desired shape and are particularly good at absorbing explosive blast energy.

Advantageously, the foam comprises polystyrene foam or phenollic foam.

In an alternative arrangement, the first material comprises vermiculite.

Conveniently, the foam may be in granular form.

In a particularly advantageous arrangement, the second material comprises powdered metal thereby enabling rapid conversion of explosive blast energy to thermal energy.

Preferably, the powdered metal comprises one or more of the following, silver, copper or gold.

Alternatively, the second material may comprise an alloy of C/Cr/Ni or a material with a low sublimation energy.

Alternatively, the second material may comprise a fluid or gel having a low latent heat of evaporation thereby allowing rapid conversion of blast energy into thermal energy by means of a phase change in the second material.

Advantageously, the second material is contained within voids in the first material.

Alternatively, the second material may cover at least part of an outer surface of the first material.

Conveniently, a protective coat such as epoxy sealant covers the first and/or second material in order to prevent evaporation of the second material.

Preferably, the second material is provided in some but not all the voids in the first material thereby to ensure the first material maintains its crushable or deformable character.

The present invention will now be more particularly described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a pictorial representation of an aircraft in part cutaway form having a number of frames exposed,

Figure 2 is a cross sectional view of a blast absorbing structure and a structurally important aircraft frame member,

Figures 3 to 5 illustrate various arrangements of the blast absorbing structure shown in figure 2,

Figures 6a and 6b illustrate still further blast absorbing structure arrangements.

Referring now briefly to figure 1, an aircraft shown generally at 10 comprises a fuselage 11 formed from a structural framework 12 covered by an outer skin of metal 14. The framework itself comprises a plurality of circumferentially extending frames 16 axially spaced from each other and a

plurality of longerons 13 which run the length of the fuselage connecting the frames 16.

Turning now to figure 2, it can be seen that the blast mitigator 20 protects the large frontal area 21 of the frames 16 from any shock wave caused as a result of an explosion in the fuselage. As the explosive shock wave or blast, travels along the length of the fuselage from the point of explosion it impacts on the blast mitigator 20 rather than the frame and hence the blast mitigator prevents impact loading of the frame which could cause structural failure thereof.

The blast mitigator 20 comprises a deformable/crushable material and operates, at least partially, by collapsing or deforming as the shock wave passes through it. Analysis of the physical principles involved as the shock wave propagates through the blast mitigator shows that it generates entropy, that is to say, it is both compressive and a rise in temperature is generated. Hence, in addition to the mechanical methods of energy extraction using crushable materials discussed above, there is also the potential for extracting energy from the wave by thermodynamic means.

To illustrate the point, it is instructive to examine the expression for the temperature jump across a shock as it propagates into a stationary perfect gas, viz.,

$$T = \frac{1}{2c_v}(p_- + p_+)\frac{\Delta\rho}{\rho_-\rho_+} \qquad \text{-----} \quad 1$$

where T is the temperature, p the pressure, $\rho$ the density, and $c_v$ is the specific heat of the gas at constant volume. The subscripts + and - refer to the state of the gas ahead and behind the shock respectively, and $\Delta f = f_- - f_+$, represents the jump in the field f across the shock.

Since $\Delta\rho > 0$, (the shock is compressive), we have $\Delta T > 0$, and therefore the thermodynamic energy associated with the transition of the shock can be extracted if heat sinks are distributed throughout the medium through which the shock propagates.

Examination of the conservation form of the total energy equation for the material through which the wave propagates gives,

$$\text{Rate of change of total energy over an increment } \delta x = u(pc_vT + \tfrac{1}{2}pu^2 + p)\delta x \qquad \text{----- } 2$$

The left hand side of the above equation is conserved over the increment $\delta x$, thereby implying that the internal energy of the medium, $pc_vT$ may increase at the expense of the mechanical work performed on the medium, which is represented by the other terms in the equation. The means of redistributing the energy is via the temperature field.

The physical mechanism for the extraction of heat energy is thermal conduction into heat sinks. These heat sinks are envisaged to be sites of material with the properties of high thermal conductivity and large thermal capacity.

In many instances, thermal conduction tends to be a process of relatively long duration. The characteristic time ( ) for thermal conduction to occur, is,

$$\tau \sim \frac{L^2}{K} \qquad \text{----- } 3$$

where L is the characteristic dimension of the heat sink and K is the coefficient of thermal conduction of the material comprising the heat sink. Clearly, the characteristic time is minimised for small heat sinks ($L^2 \longrightarrow 0$), and materials of high thermal conductivity ($K \longrightarrow \infty$).

In order to provide a fully effective blast mitigator which is capable of absorbing shock energy by thermodynamic as well as mechanical means it is proposed to distribute heat sinks 30 throughout the crushable material.

Figure 3 illustrates a first of a number of alternative blast mitigator compositions. A first crushable/deformable material 32 such as a polystyrene foam, a phenollic foam or even crushable vermiculite for example provides a carrier in which a second material 34 having the properties of high thermal conductivity and large thermal capacity is suspended. The second material comprises suspended grains of powdered metal 34 or a material with a low sublimation energy spread amongst the first material. When an explosive blast impinges upon the first material and starts to crush/deform it, the powdered metal grains absorb a portion of explosive blast energy by absorbing a portion of the heat generated in the first material as it is crushed/deformed.

Clearly, from equation 3 above, the smaller the individual grains and hence the larger the volume/unit surface area the better. Materials having high thermal conductivities such as silver, copper or gold will enable higher heat transfer rates to be achieved. In some circumstances it could be advantageous to use alloys such as a combination of C/Cr/Ni.

Whilst figure 3 illustrates the second material suspended in the first material it will be appreciated that the second material could be provided by way of an outer layer over the first material as shown in figure 4. In this arrangement, the second material is fragmented as the explosive shock hits the blast mitigator 20 and driven into the first material as the blast wave propagates. As the second material passes through the first, it absorbs heat energy contained in the first material as a result of crushing/deforming thereof or generated as a result of friction between the two materials. Vermiculite lends itself more particularly to use in combination with a coated second material whilst foams are suitable for coating or impregnation with the second material.

Figure 5 illustrates an alternative arrangement in which the second material 34 takes the form of a liquid or gel 36 suspended in the first material 32. Fluids and gels generally have a low latent head of vaporisation that is the amount of heat required to convert a unit mass of a substance from liquid to vapour without change in temperature. Given sufficient blast energy the fluid or gel will experience a rapid compression which can result in a phase change and an associated extraction of energy from the

shock wave. In addition to this, the hydrodynamic interaction of the shock wave with the fluid or gel provides a complementary mechanism which may also act to dissipate the shock wave energy.

As mentioned above for the powdered metal structure, there are two ways in which the fluid/gel may be incorporated in the blast mitigator 20. The first involves impregnation of the crushable/deformable first material with the fluid/gel whilst the second involves coating the first material 32 with the gel 38. Turning now to figures 5 and 6, the crushable/deformable material is, preferably porous, in which case, the fluid/gel may be impregnated into the pores thereof by any conventional technique. Vermiculite and open cellular foams lend themselves particularly well to impregnation. It may be necessary to provide a protective coating 40 over the outer surface of the blast mitigator structure in order to prevent evaporation or leakage of the fluid/gel. Alternatively, a self sealing gel could be used. Non porous crushable/deformable materials may be used if the fluid/gel is introduced into said material during manufacture, or coated on the outside thereof.

Figure 6 illustrates an arrangement where the crushable material is non-porous and comprises, for example, a plurality of cellular foam beads 42. The beads themselves may either be injected with micro-globules of the fluid or gel (figure 6a) or may be coated with the gel (figure 6b). In either case, a protective coat of epoxy sealant should be applied in order to

prevent evaporation and/or inhibit the beads 42 sticking together.

## CLAIMS

1. A blast absorbing structure comprising a first deformable/crushable material for absorbing explosive blast energy by way of conversion to mechanical work and a second material for absorbing explosive blast energy by way of conversion to thermal energy.

2. A blast absorbing structure as claimed in claim 1 in which the first material comprises a foam.

3. A blast absorbing structure as claimed in claim 2 in which the foam comprises polystyrene foam or phenollic foam.

4. A blast absorbing structure as claimed in claim 2 or claim 3 in which the foam is in granular form.

5. A blast absorbing structure as claimed in claim 1 in which the first material comprises vermiculite.

6. A blast absorbing structure as claimed in any one of the preceding claims in which the second material comprises powdered metal thereby to enable rapid conversion of explosive blast energy to thermal energy.

7. A blast absorbing structure as claimed in claim 6 in which the powdered metal comprises one or more of the following silver, copper or gold.

8. A blast absorbing structure as claimed in claim 6 in which the powdered metal comprises an alloy of C/Cr/Ni.

9. A blast absorbing structure as claimed in any one of claimed 1 to 5 in which the second material comprises a material having a low sublimation energy.

10. A blast absorbing structure as claimed in any one of claims 1 to 5 in which the second material comprises a fluid or gel thereby to allow the rapid conversation of blast energy into thermal energy by means of a phase change in the second material.

11. A blast absorbing structure as claimed in any one of the preceding claims in which the second material is contained within voids in the first material.

12. A blast absorbing structure as claimed in any one of claims 1 to 8 in which the second material covers at least part of an outer surface of the first material.

13. A blast absorbing structure as claimed in any one of the preceding claims including a protective coating over the first

and/or second material to prevent evaporation of the second material.

14. A blast absorbing structure as claimed in claim 12 in which the protective coating comprises an epoxy sealant.

15. A blast absorbing structure as claimed in claim 12 in which the protective coating comprises the second material itself which is self sealing where exposed.

16. A blast absorbing structure as claimed in claim 9 in which the second material is provided in some but not all of the voids in the first material.

**Patents Act 1977**
**Examiner's report to the Comptroller under Section 17 (The Search Report)**

Application number

9126441.6

**Relevant Technical fields**

(i) UK Cl (Edition K ) A5A; B7W (WC,WFH,WFX); C3C;C3N

(ii) Int Cl (Edition 5 ) A62C, B64C

Search Examiner

C J LUCK

**Databases** (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: CLAIMS, WPI

Date of Search

20.3.92

Documents considered relevant following a search in respect of claims

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| X | GB 2238283 A (ROYAL ORDNANCE) see page 8 lines 1-3 | 1,2 |
| X | GB 1485828 A (BOLIDT) see page 3 line 22 and Example 3 | 1,2,3,6 |
| X | GB 1386887 A (LIEVREMONT) see page 1 lines 28, 29, Examples 1, 2 | 1,2,3,6 |
| X | GB 1357003 A (BAC) see page 2 line 1 | 1,2,3,6 |
| X | GB 1129112 A (INSTITUT DU PETROLE) see page 2 lines 15-22 | 1,2,3,6, 7 |
| X | GB 1118277 A (CONTRAVES) see page 4 lines 44-47 | 1,2,3,6, 14 |
| X | GB 1070874 A (HAMBURGER) see page 3 lines 2, 3 | 1,2,3 |

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| Category | Identity of document and relevant passages | Relevant to claim(s) |
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